JOHN F. KENNEDY SCHOOL OF GOVERNMENT

HARVARD UNIVERSITY

ADAPTING AIR FORCE PRACTICES TO COPE WITH A VANISHING INTEGRATED CIRCUIT SUPPLY BASE

MAINTAINING THE TECHNOLOGICAL EDGE

POLICY ANALYIS EXERCISE
CLIENT: RAND CORPORATION, PROJECT AIR FORCE TEAM
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APRIL 4, 2000

ABOUT THIS POLICY ANALYSIS EXERCISE

This Policy Analysis Exercise (PAE) was developed in consultation with RAND Corporation's Project AIR FORCE (PAF) Team. PAF is a Federally Funded Research and Development Center that has been providing analysis to the Air Force for over fifty years. The mission of the Project AIR FORCE Team is "to conduct an integrated program of objective analysis on issues of enduring concern to the leaders of the Air Force."[1]

EVOLUTION OF THE SCOPE AND FOCUS OF THIS POLICY ANALYSIS EXERCISE

This Policy Analysis Exercise began with a meeting between the author and the client, RAND Corporation's Dr. Cynthia Cook. Dr. Cook provided an idea that has evolved over the course of the time spent researching this paper. RAND was interested in learning more about the relationship the Air Force has and should have with respect to its suppliers of strategically important materiel; more specifically, the relationship the Air Force has with suppliers of strategically important materiel *with whom the Air Force has little bargaining power.*

The source of the idea for analyzing this relationship was Christopher S. Tang's article "Supplier Relationship Map," which defined sets of relationships between purchasers and suppliers in the business world. Tang constructs a matrix that is useful in identifying the type of relationship that a purchasing firm will want to achieve with its suppliers. This relationship, according to Tang, is determined by "two key factors . . . *strategic importance of the part to the buyer* and *buyer's bargaining power.*"[2] RAND is trying to help the Air Force implement innovative commercial practices overall, and as a

[1] RAND Corporation, Project AIR FORCE Website. http://www.rand.org/organization/paf/about.html

[2] Tang, Christopher S. "Supplier Relationship Map." *International Journal of Logistics: Research and Applications,* Vol. 2, No. 1, 1999, 43.

part of that effort was interested in learning about the Air Force relationship with the firms who would fall in the category of providing parts of strategic importance, but over whom the Air Force had relatively little bargaining power. This exactly describes the Air Force's relationship with integrated circuit (IC) suppliers.

Initially, the idea was for this PAE to compare the IC purchasing practices of innovative private sector firms with those of the Air Force, and from this comparison attempt to develop some "best practices" from the business world that the Air Force could apply to its IC purchasing operations. It was determined that this would be beyond the scope of this PAE. However, some commercial world practices have informed the author's perspective on the subject.

ACKNOWLEDGEMENTS

The author would like to thank the following people:

Dr. John White, Harvard University. For going through more drafts than he ever dreamed and for always making time for me in his busy schedule. Thank you Dr. White for your patience and your help in refining my thoughts. Your concern for your troops is obvious to us all.

Dr. Cynthia Cook, Project AIR FORCE, RAND Corporation. For getting me started on this project and for helping me through the research process. The contacts you helped me find really formed the core of my research. I know you loved editing drafts of this report while you were on the road. Thank you also for your patience.

Lillian Politser, Harvard University. For always finding a way and a time for me to meet with Dr. White. You are truly committed to helping the students at the Kennedy School. Thank you.

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LIST OF MAJOR ACRONYMS

ACC – Air Combat Command. Air Force Major Command responsible for conduct of air combat operations.

AFMC – Air Force Materiel Command. Air Force Major Command responsible for development, testing, and sustainment of Air Force weapon systems.

AFMC DMSMS Program – Air Force Materiel Command Diminishing Manufacturing Sources and Material Shortages Program. Also called the Hub.

ALC – Air Logistics Center.

ASC – Air Systems Command. Arm of Air Force Materiel Command responsible for the development of new airframes and other weapon systems. SPOs fall under Air Systems Command authority.

CCIP – Common Configuration Implementation Program. Current avionics upgrade program for the USAF F-16.

CLS – Contractor Logistics Support. Current proposed contract for Lockheed-Martin's support of the F-22.

CLTS – Combined Lifetime Support. Current contract for contractor support of major avionics and other systems on the F-16.

COTS – Commercial-off-the-shelf. Refers to the purchase and use of commercially available standard products for military applications. (versus MILSPECS)

DMS – Diminishing Manufacturing Sources. A part is termed DMS when its production is terminated or will be terminated.

FRY – Federal Republic of Yugoslavia.

IC – Integrated Circuit.

MILSPECS – Military Specifications. Refers to the set of traditional standards required by military users when purchasing products from suppliers. For integrated circuits, refers to the environmental standards required – radiation hardening, temperature range, g-force sustenance, etc.

MPCL – Military Products from Commercial Lines. Pilot program in the F-22 program wherein the F-22 support team purchases COTS ICs from a major automotive IC producer and "ruggedizes" them to the standards required for use in the F-22.

SPO – System Program Office.

USAF – United States Air Force.

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This PAE serves three functions:

(1) To explain the complex problems associated with the Air Force's vanishing integrated circuit supply base.

(2) To analyze the Air Force process for dealing with this vanishing supply base.

(3) To recommend some changes to Air Force practices that will enable the Air Force to efficiently keep its systems supplied with circuits for the future.

Importance of Avionics Dominance on the Modern Battlefield. According to General Richard E. Hawley (USAF Retired), former commander of Air Force's Air Combat Command, "Everything that we must do to prevail on tomorrow's battlefield depends on our ability to dominate the skies over that battlefield."[3] Air dominance relies in part on avionics dominance.

In the world of today's combat aircraft, avionics are a critical determinant of combat outcomes. Avionics dominance helped provide swift and complete air dominance in Operation DESERT STORM and enabled the success of the US air campaign in Kosovo, Operation ALLIED FORCE.

General Hawley's sense of the future summarizes well the reason for addressing an avionics-related problem in this PAE: "Air dominance grows more difficult to achieve as modern weapons

[3] Hawley, Richard E. "F-22 A Needed Fighter." *The Washington Times,* July 26, 1999, 17.

proliferate across the globe."[4] It would be a grave misjudgment to assume from our successes in DESERT STORM and ALLIED FORCE that our air forces will never be asked to face off against more technologically robust foes.

The Problem. Integrated circuits serve as the "brains" for USAF avionics system. But the Air Force is losing its integrated circuit suppliers.

Because Air Force fighters are using old circuits, they often face the problem of a diminishing or even vanishing supply base. These older circuits face a lack of demand, making them "business obsolete." The lack of demand for these circuits causes integrated circuit producers to terminate production of low-demand ICs. This market flight places Air Force support teams in a difficult situation, faced with the challenge of keeping these "business obsolete" ICs in their aircraft, but with their suppliers shifting to more lucrative production. This dynamic is termed DMS (Diminishing Manufacturing Sources).

Current USAF Efforts. To provide a focus for this study, and to appeal to the leadership of the Air Force, two case studies are used to shed some light on the problem: the F-16 and the F-22. These represent the backbone of the present Air Force fighter structure and the prized future fighter of the Air Force. Both programs have developed separate and effective *reactions* to DMS occurrences. Both programs have also taken significant steps toward developing *proactive* solutions to DMS occurrences. Significant structural barriers still exist, however, to developing a truly efficient DMS response.

[4] Hawley, Richard E. "F-22 A Needed Fighter." *The Washington Times*, July 26, 1999, 17.

Critiques of Current Practices. (1) Air Force data management for its weapon systems has been poor. For example, no one knows exactly how many parts are in an F-16 – only estimates exist. (2) The response to DMS problems as it stands requires action from myriad offices across the nation. No unified DMS response exists. (3) To deal with DMS problems, each weapon system must fight for its own budget resources, from Congress directly or from Air Combat Command. This is compounded by problem (4): there is a general lack of respect for this problem within the Air Force. This is partly a problem of packaging and selling the need for more effective proactive DMS solutions.

Recommendations. (1) The Air Force must complete a program (called the API) for cataloging each component of its weapon systems in a common database. (2) Proper and complete data must be used to enable the Air Force to utilize the existing analytical tools that can predict DMS occurrences. (3) Air Force managers must use these predictive tools to predict and plan for DMS occurrences in existing weapon systems. (4) Air Force engineers should use these predictive tools to build avionics systems that use DMS-resistant integrated circuits. (5) AFMC must be given an overall budget for DMS in proportion to the amounts spent on this problem yearly. (6) Affected personnel in SPOs, ALCs, and at the AFMC DMSMS Program must come up with creative and engaging ways to "sell" the importance of this problem to Air Force leaders – from the top down.

Conclusion. Avionics will remain the strategic component of Air Force aircraft for the foreseeable future. The vanishing IC supply base challenges this avionics dominance. Taking the steps to develop predictive tools and adopt a more proactive DMS stance are the key components of a "smart" strategy for dealing with the hyper-acceleration of the IC market.

INTRODUCTION

THE AIR FORCE STRATEGIC ENVIRONMENT: A WARFIGHTER'S PERSPECTIVE

Today's United States is a global actor with global interests. The United States Air Force Vision expresses well the Air Force's contribution to protecting global US interests: "Global Reach, Global Power."

The Air Force operates within the parameters of the increasingly uncertain modern international security environment. One of the most pressing concerns for today's Air Force is the global proliferation of sophisticated weapon systems – and not only nuclear weapons.

The most threatening proliferation for Air Force fighter aircraft is occurring in the surface-to-air missile arena. Iraq, North Korea, Iran, and Pakistan are a short list of surface-to-air missile program proliferators. The collapse of the Warsaw Pact especially has contributed to the spread of former Warsaw Pact assets and technology across the globe.

A second development also causes concern for today's Air Force leadership. A number of foreign fighter aircraft stand poised for operational activity which would outpace current Air Force tactical fighter systems (F-15 and F-16). Fighters of concern to the Air Force include the MiG-29, Su-27, Eurofighter, and the French Rafale.[5]

[5] Hallion, Richard P. "Why We Need the F-22." *The Washington Post,* July 22, 1999, 23, and Ivan Eland "... Or A Fantasy?", *The Washington Times,* July 26, 1999.

The fundamental challenge these systems could pose to our Air Force fighters comes in the electronic systems that could provide them first-look, first-shot, first-kill capability. Aerial combat today often takes place between combatants who never come within visual range. These combatants rely on advanced electronic systems for detection, identification, and targeting of enemy aircraft. The US Air Force's dominance in advanced technological capabilities has been a major factor in the success of US Air Force campaigns for the last decade. Operation DESERT STORM showcased US Air Force technological capability and Operation ALLIED FORCE again demonstrated the advanced capabilities of US airpower. The US Air Force has demonstrated that its weapon systems *today* are world leaders in technology.

The global proliferation of high performance weapon systems is all the more crucial because the Air Force has increasingly become the tool of choice for US policymakers as a uniquely capable and relatively casualty-free rapid reaction force. Operation ALLIED FORCE in Kosovo demonstrated this unique facet of US airpower. US airpower formed the core of the force applied to achieve NATO political aims in the Balkans, with a zero casualty rate among NATO forces. The growing tendency to apply the airpower tool means that the US Air Force must be prepared to enter combat anywhere, anytime. And this means that Air Force technology must be the best in the world to guarantee its utility as a policy tool for the United States.

But the Air Force pole position in aviation electronics technology is in jeopardy. One of the most valuable lessons of ALLIED FORCE is that it demonstrated the vulnerabilities in our Air Force. In testimony before the Senate Armed Services Committee on October 14, 1999, Secretary

of Defense Cohen and Chairman of the Joint Chiefs of Staff General Shelton provided an assessment of the air defenses employed by the Serbs:

> *"FRY air defense systems did not represent state of the art. Much more capable systems are available for sale in the international arms market. In the years ahead, we may face an adversary armed with state-of-the-art systems, and we need to prepare for that possibility now."*[6]

Air Force leadership must not take its technological superiority for granted. Many Air Force programs for modernization and upgrade demonstrate that this is not the case; Air Force leaders clearly understand the importance of our technological "edge" in combat. However, one technology issue has not received the same high priority that will have a major effect on our technological edge in future combat: the frail supply chain that keeps integrated circuits in our modern avionics systems. Without some major revisions to the Air Force approach to its IC supply chain, that tenuous supply line could become a debilitating obstacle in preparing for the possibility of a technologically superior foe.

HOW INTEGRATED CIRCUITS IN FIGHTER AIRCRAFT ARE IMPORTANT FOR AIR FORCE OBJECTIVES

ICs are important for the Air Force because (1) they power the avionics systems in Air Force fighters and (2) the Air Force is losing suppliers of its ICs.

[6] Joint Statement of William S. Cohen, Secretary of Defense, and General Henry H. Shelton, Chairman of the Joint Chiefs of Staff, Senate Armed Services Committee on Kosovo After-Action Review, October 14, 1999, 12.

DOCTRINAL PERSPECTIVE: NUMBER ONE PRIORITY IS AIR SUPERIORITY

From a warfighter's perspective, Air Force air superiority fighters form the first tier of the rapid reaction airpower tool. The pilots of these aircraft are tasked with the number one priority of any aerospace force: achieving air superiority.[7] Air superiority means that US and allied aircraft can fly in the conflict airspace with confidence that they are well protected from enemy air threats, be they air-to-air or surface-to-air. The Air Force Doctrine Center defines this highest priority: "Air and Space Superiority is a crucial first step in any military operation. It provides *freedom from attack, freedom to maneuver,* and the *freedom to attack* necessary for success in air, land, space, or sea operations."[8] Once air superiority has been achieved, important systems like the Air Force's Airborne Warning and Control System (AWACS) and Joint Surveillance Targeting Attack Radar System (JSTARS) can fly unharmed in the conflict area and provide the crucial targeting, intelligence, and coordination information that allow US and allied forces to execute integrated military operations. Owning the skies in an area of conflict is therefore a strategic prerequisite for employing force in the battlespace.

How does the Air Force go about achieving air superiority? Air Force doctrine stipulates that tactical fighter aircraft (air superiority aircraft) eliminate the enemy air-to-air threats, allowing the operation of other fighter and bomber aircraft to eliminate surface-to-air and other ground-based air defense systems. Currently the F-15C performs the air superiority mission; the F-16 and a combination of other Air Force fighter, bomber, and air-to-ground platforms perform the bulk of

7 Air Force Doctrine. According to the Air Force Doctrine Center, the first Core Competency of Aerospace Power is "Air and Space Superiority." See, for example, Air Force Doctrine Center website: http://www.doctrine.af.mil

8 Air Force Doctrine Center "Doctrinaire's Primer." Available at http://www.doctrine.af.mil/Main.asp

the remaining missions, eliminating some air-to-air threats but concentrating on surface-based threats.

AVIONICS: CRITICAL ENABLER RELIANT ON INTEGRATED CIRCUITS

Aviation electronic systems are one of the critical tools that allow USAF fighter aircraft to perform these missions successfully. Avionics is a shorthand term meaning aviation electronics. Avionics refers to the systems on an aircraft that perform specific electronic tasks, such as radar, fire control, targeting systems, or Communication, Navigation, and Identification (CNI) systems. Avionics systems have added versatility, lethality, and survivability to every Air Force fighter. The F-16 "has undergone six major block changes incorporating four generations of core avionics."[9] These changes have transformed the F-16 from a daytime air-to-ground and air-to-air fighter into an all-weather, night capable, precision strike aircraft with highly advanced radar detection and identification systems.

F-16s rolling off the assembly line today are drastically different in capability than those that the Air Force first put to use in the 1970s. The aircraft do not look that different, but their combat capabilities are light years apart. This is because the airframe and propulsion systems for the F-16 have not changed as drastically or improved its capabilities to the same degree as avionics changes.

For example, with the addition of the Low-Altitude Navigation Targeting Infrared for Night (LANTIRN) system, the F-16 gained the capability to attack ground targets at night with great precision and lethality.

9 Lockheed-Martin Aeronautics Company, Fighter Programs Division. F-16 Fighting Falcon: Status. http://www.lmtas.com/Fighter_Programs/F16/f16status.html.

Without a steady stream of ICs to power our avionics capabilities, the Air Force cannot capitalize on the technological advantages that superior avionics provide in battle. And vanishing suppliers of ICs jeopardize the future of that steady stream for Air Force fighters.

PURPOSES OF THIS POLICY ANALYSIS EXERCISE

This PAE's broad goal is to raise awareness and understanding of an important and complex problem facing Air Force Materiel Command. The specific purposes of this report are:

(1) To explain the complex problems associated with the Air Force's vanishing integrated circuit supply base.

(2) To analyze the Air Force process for dealing with this vanishing supply base.

(3) To recommend some changes to Air Force practices that will enable the Air Force to efficiently keep its systems supplied with circuits for the future.

PROBLEM STATEMENT: THE AIR FORCE IS LOSING ITS INTEGRATED CIRCUIT SUPPLIERS

Suppliers of integrated circuits for the US Air Force are exiting the military market in favor of more profitable customers. The flight of suppliers from the military IC market has left Air Force weapon systems managers scrambling for solutions to supply their aircrafts' systems with replacement ICs. *Because of a lack in current Air Force capabilities for dealing with these challenges, Air Force*

support personnel are forced to adopt reactive and wasteful practices for ensuring the flow of replacement integrated circuits to its fighter aircraft.

Air Force Materiel Command (AFMC) is responsible for the support of Air Force weapon systems. The AFMC acronym for describing a part that is no longer produced or will soon no longer be produced is DMS: Diminishing Manufacturing Source. Occurrences of DMS in integrated circuits are blossoming. For example, the F-16 DMS Manager reports that DMS occurrences in the F-16 program accelerated from 2 cases in FY94 to over 600 in FY98.[10] The acceleration of DMS occurrences is creating major problems in sustaining weapon systems now – which are being managed well – but in the future, significant changes in technology will make the problem unmanageable by current practices.

Specifically, three distinct problems present challenges to Air Force Materiel Command in sustaining a supply of ICs for the fighter aircraft it supports.

Problem (1): A number of the ICs in current-use USAF avionics system are no longer produced; their manufacturer(s) have exited the market. Often the Air Force receives this information on very short notice or discovers this occurrence through an unsuccessful attempt to purchase the discontinued part. What steps can be taken to continue the flow of replacement ICs to the fighter aircraft?

Problem (2): A number of ICs currently in use in USAF avionics systems on the F-16 and F-22 are still being produced by their manufacturers, but those manufacturers will exit the

[10] Interview, Mr. Michael Jackson, F-16 ALC, Ogden, Utah, 15 MAR 00. Air Force Lieutenant Colonel Vince Adamski actually submitted a letter to Headquarters, Air Force Materiel Command detailing this specific explosion of DMS cases and requesting some additional DMS funding and centralization. The letter, sent out under his commander's signature – as an Air Combat Command member -- was never acted on.

market sometime in the future. Often these manufacturers give Air Force support personnel little or no notice of their product discontinuance in order to remain competitive in the market. What steps can the Air Force take to prevent a situation where its avionics systems rely on out-of-production ICs?

Problem (3): When selecting a new IC for use in an avionics system, the Air Force must recognize the possibility of the vendor for that IC discontinuing production before the Air Force's operational needs end. What steps can the Air Force take to provide itself the ability to avoid, or at least decrease the probability of, this situation when selecting a new IC?

The problem is serious enough that in potential future scenarios there could be no method for getting the necessary quantity of ICs into certain systems in the F-16, the F-22, or other Air Force assets in a timely manner. Major technological differences will exist between current Air Force-employed ICs and any IC available in the marketplace. The acceleration of such a development would surely ground aircraft.[11] *Eventually these technological changes will so revolutionize the market that the Air Force will have no other option but to discontinue use of older-generation ICs whose suppliers no longer exist. These ICs will simply not be available in sufficient quantity from any source. Without a proactive mechanism to prevent this occurrence, Air Force avionics systems will deplete their replacement IC base and be forced out of service.*[12]

One of the goals of this PAE therefore is to help AFMC move from a reactive approach to DMS to a proactive approach. That is, rather than waiting to be notified of parts discontinuance,

[11] Interview, Mr. Michael Jackson, F-16 Air Logistics Center, Ogden, Utah, 20 MAR 00. One of the most significant changes in ICs that will affect the future of the F-16 is the switch from the 5-volt standard to the 3-volt standard and lower.

[12] Jackson, Michael S., Air Force Point Paper: "Industry Standard Shift from 5 Volt to 3 Volt Systems." For a copy, contact: Mr. Michael Jackson, OO-ALC/LFRC, (801)777-9303.

AFMC would be able to predict and plan for parts discontinuance and use that knowledge to inform its decisions for resolving DMS cases, or to prevent DMS cases from occurring through the use of DMS-resistant ICs.

A NOTE ON TERMINOLOGY

Air Force terminology for supplier-loss is somewhat confusing. DMS is often used as a synonym for obsolescence, and vice versa. **DMS mean that the supplier for the particular part has terminated production of that part.** Obsolescence, however, can have two meanings. **Technical obsolescence of an IC means that it is sub-state-of-the-art.** That is, the IC has been replaced on a broad basis by a better-performing IC. **Business obsolescence means that the IC is no longer profitable to produce.** Business obsolescence is generally a result of a lack of demand. An IC can become technically obsolete but still have sufficient demand to allow for profitable production.

In this report, DMS will refer to a part whose production has been terminated, or will soon be terminated – meaning that the business decision to end production has already occurred . Obsolescence will be used in the business obsolete sense. The two concepts are not exactly the same. A part can be business obsolete, but still in production because the vendor has not yet terminated the manufacturing process. A DMS part is one for which termination has already occurred or for which termination will occur before Air Force needs for the part end.

WHY LOSING INTEGRATED CIRCUIT SUPPLIERS IS AN IMPORTANT PROBLEM FOR THE AIR FORCE

Clearly, human factors play a major role in the outcomes of aerial combat; training, tactics, and doctrine are crucial factors in any military conflict. Equally clearly, US training and tactics are

superior to that of any air force across the globe. Technological advantages, however, can tilt the scales in the favor of one combatant.

Integrated circuits are of great importance to the Air Force because they are the *most at-risk* link in the complex support chains that power Air Force avionics systems.

As the "brains" of avionics systems, ICs are also a core determinant of system performance. Avionics system performance is the most critical *technological* variable in determining combat outcomes for fighter aircraft. Superior avionics systems provide the warfighter with first-look, first-shot, first-kill capability. ICs therefore can provide Air Force fighters with greater lethality and greater survivability.

Air Force fighter aircraft are tasked with the mission of eliminating enemy air threats in order to provide air superiority. For the foreseeable future, fighters will continue to rely on avionics as the key technological edge in achieving air superiority. Avionics systems require ICs to function. The at-risk nature of the IC supply chain is thus of strategic importance to the US Air Force in successfully performing its global mission.

> *"If I didn't have air supremacy, I wouldn't be here." -Dwight D. Eisenhower, Normandy, 1944*[13]

Air superiority is the enabling prerequisite for all successful military operations. General Eisenhower clearly understood this. In World War II, the fundamental differences in aircraft came

[13] Quoted from: Hallion, Richard P. "Why We Need the F-22." *The Washington Post*, July 22, 1999, 23.

in airframe and propulsion – range, top speed, and turn radius were especially key. But achieving air superiority today is less and less a question of airframe or propulsion, and more and more a question of avionics superiority.

The debate over funding and production of the F-22 reveals the strategic importance of avionics for the future of US Air Force operations. No matter which side of the issue one chooses to take, both proponents and opponents of the F-22 generally begin from the premise that avionics form the fundamental "break" between superior aircraft and their lessers. For example, Ivan Eland, a prominent F-22 critic and Director of Defense Policy Studies at the Cato Institute, argues that "In an age when success in warfare depends more and more on electronics and precision weapons, quantum improvements in the air platforms that carry such devices are less necessary."[14] Mr. Eland takes the position that the F-15 could be upgraded with the necessary avionics capabilities to overcome any potential air-to-air threats with a lower price tag than the F-22.

Why is it important for the Air Force to be worried about avionics dominance in light of US conventional military superiority? Most simply, because we never know what capability future foes may possess. The only way to make sure that we are not "surprised" with a superior system is to assure our own systems remain top-of-the-line. In an article responding to the House Appropriations Committee's vote to cancel $1.8 billion in funding for the F-22, General Hawley provided his veteran perspective:

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[14] Eland, Ivan. ". . . Or A Fantasy?" *The Washington Times,* July 26, 1999, 17.

> *"It seems that our ability to dominate the skies over Yugoslavia has been taken to mean that there is no need to modernize the Air Force's air superiority fighter force. The House seems to have concluded that our armed forces will never be asked to fight a foe with more robust capabilities than those we have just defeated."*[15]

A constant vigilance has provided the US with conventional military superiority today, and only continued constant vigilance will provide it tomorrow.

To explain more fully, let us take an example. In the air operations in both Bosnia and Kosovo, US intelligence was unable to determine in detail the capability of the Integrated Air Defense System of the Former Republic of Yugoslavia. Because of the difficulty in assessing these systems' technological advancement, initial estimates were uncertain of combat outcomes. Had these air defenses been equipped with superior technology to that of the Air Force fighters in the sky, it is likely that policymakers would not have viewed airpower as the option of choice. Technological parity is not enough for USAF systems to remain a useful tool in the modern security environment. But technological parity may be the future if we are not careful to continually assess and monitor the status of our military forces – especially our fighter aircraft. Had the Integrated Air Defense System that Serbian forces inherited from the Soviet-supplied JNA had better systems in its surface-to-air missiles, US policymakers may have determined that airpower would not provide a viable policy tool for achieving US objectives in Kosovo.

[15] Hawley, Richard E. "F-22: A Needed Fighter." *The Washington Times*, July 26, 1999, 17.

Avionics are also more critical today because of the commonality that exists among many nations in terms of airframes. Nineteen nations now own some version of the F-16 fighter discussed in this report: the US, Belgium, Denmark, The Netherlands, Norway, Israel, Egypt, Republic of Korea, Pakistan, Venezuela, Turkey, Greece, Singapore, Thailand, Indonesia, Bahrain, Portugal, Taiwan, and Jordan.[16] In the past, differences in avionics systems have clearly preferred US Air Force aircraft. The recent sale of the most highly advanced version of the F-16 (the Block 60) to the United Arab Emirates has triggered a debate about whether this sale could endanger US Air Force avionics dominance.[17]

The specific features of the Block 60 F-16 of most concern, or most "to be envied by U.S. pilots" are:[18]

- "An active electronically scanned array (AESA) radar that produces a classified 70-80 mi. range against a 1-meter-square target. That's about 10-20 mi. better than the current top of the line F-15C interceptor and three times better than the current USAF F-16. The longer-range radar will make the F-16 a much more lethal platform for employing beyond-visual-range air-to-air missiles such as the AIM-120. Moreover, it employs frequency hopping for low-probability of intercept operation, a technique to slow detection by a foe."

- "An electronic warfare package that includes the most advanced electronic countermeasures and radar countermeasures."

16 Lockheed-Martin Aeronautics Company: Fighter Programs, F-16 Fighting Falcon. Customers. http://www.lmtas.com/FighterPrograms/F16/f16_customers.html.

17 See, for example, David A. Fulghum, John D. Morrocco and Edward H. Phillips' "UAE's F-16s Will Be Envy of USAF Pilots," in *Aviation Week & Space Technology*, March 13, 2000, 24.

The capabilities of the UAE F-16 importantly derive from avionics systems on the Block 60 (radar and electronic warfare (EW) packages) rather than airframe or propulsion dimensions. The point here is not that the US Air Force will likely have to enter combat with the UAE soon. The point is that in a nation with global interests, the US Air Force must be the best on the globe – and our global competitors will continually seek their own force improvements.

To maintain a position of avionics dominance, the Air Force must ensure that each strand of the complex avionics supply chain provides a high-quality, continuous flow of materiel to its avionics systems. The quality and continuity of the integrated circuit strand of this chain is at risk because of diminishing IC manufacturing sources. The Air Force must adapt its practices for dealing with vanishing IC suppliers or face the possibility of losing its edge in avionics dominance. Losing this edge would endanger the viability of airpower as a US policy tool of choice.

WHY THE AIR FORCE IC SUPPLY BASE IS AT RISK

The Air Force IC supply base is at risk because of the small and declining importance of the Air Force as a customer in the IC market. Business incentives drive suppliers to exit the military market for higher-volume, more profitable customers.

Because ICs are evolving at an ever-quickening pace, IC producers manufacture certain ICs for shorter and shorter periods of time, switching to newer, more profitable ICs. Given today's lengthy aircraft service lives, this means that manufacturers will discontinue production of an in-use IC more often over the lifetime of each aircraft.

[18] This information comes from David A. Fulghum, John D. Morrocco and Edward H. Phillips' "UAE's F-16s Will Be Envy of
(footnote continued)

DOD DECLINING MARKET SHARE

The military share of the integrated circuit market has decreased from 17 percent in 1975 to less than one percent today[19]. Leading-edge producers of integrated circuits thus have placed their priorities with other, higher-volume customers. The explosion in the use of ICs in home and industrial use in nearly every modern machine has made the Air Force, even the entire Department of Defense, a much less important customer. This undeniably weak market power places the Air Force in a weak bargaining position with its integrated circuit suppliers.

But this weak bargaining position does not change the importance of ICs for Air Force avionics dominance. It makes more critical the need for the Air Force to address and carefully manage the problem.

In dealing with IC suppliers, DoD is a unique customer. First, DoD's operational requirements mean that its assets are all over the world, and constantly moving. This is especially true for oft-deployed Air Force aircraft. Further, these assets are in constant use: the operational tempo in the Air Force today is extremely high. And Air Force weapon systems require a higher degree of "ruggedness" in ICs than almost any commercial IC consumer. ICs for use in fighter aircraft must meet higher standards for temperature range, radiation survivability, and g-force sustenance.

DoD as a spender of public funds also must implement mechanisms to assure that this money is spent carefully. In efforts to control costs, DoD has implemented a series of measures and controls meant to monitor spending and safeguard against wasteful use of tax dollars. These regulatory

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USAF Pilots," in *Aviation Week & Space Technology*, March 13, 2000, 24.

[19] Interview, Mr. Michael Jackson, F-16 Air Logistics Center, Hill Air Force Base, Utah. 20 MAR 99.

procedures for doing business with DoD are not attractive to commercial IC vendors that have the opportunity to contract with more lucrative and less bureaucratic clientele.

Loyd W. Condra et al substantiate this trend in their article "Electronic Components Obsolescence" when they argue that "[c]omponent manufacturers are exiting the military component markets to compete globally in high volume markets such as computers, telecommunications, and consumer appliances."[20] The Air Force has a challenge ahead of it then if it wishes to maintain its electronics dominance: adapt to the hyper-acceleration of the IC marketplace.

Because of the importance of ICs for future Air Force operations and these unique characteristics of DoD, the Air Force needs to have a strategy to help keep it "in the game" with its IC producers.

DRIVING FACTORS

Two factors compound the USAF's decreasing market importance: longer aircraft lifespans and decreasing IC lifespans. As weapon systems grow older, the ICs in their systems become technically obsolete – that is, they no longer represent the state-of-the-art in ICs. This is of concern itself. But often they also become obsolete in business terms – meaning that sufficient demand for the product no longer exists for profitable production and IC producers exit the market. The Air Force discovers that these producers are shutting down their manufacturing lines in various ways.

[20] Condra, Loyd W., Amir A. Anissipour, and Dennis D. Mayfield. "Electronic Components Obsolescence." *IEEE Transactions on Components, Packaging, and Manufacturing Technology*, 20a:, 03 SEP 97, 368-371.

Sometimes the producer will issue a product discontinuance notice; sometimes the Air Force will attempt to purchase the part and discover that the part is no longer produced.

The Air Force, even in conjunction with other services, cannot exercise the same type of influence in the IC market that it has in the past. That past, however, is the environment in which the Air Force developed its systems for design, testing, and acquisition of materiel. Add this to the fact that right now a new, faster, and more capable IC is introduced every 18 months[21] and it becomes even more clear that the Air Force needs to think very critically about how it will keep ICs in its aircraft without major changes in its approach to this enormously important supply problem.

LONG AIRCRAFT CRADLE-TO-GRAVE LIFECYCLE

Today's weapon systems typically undergo 15 years of design and testing before reaching the phase of an operational system. Initial Operating Capability (IOC) generally is not reached for another 5 years after that point for modern fighter aircraft. The F-22, for example, began in 1985 as a concept called the Advanced Tactical Fighter (ATF).[22] The ATF then went through at least two competitive prototypes for a number of years, the YF-22 and the YF-23. The YF-22, Lockheed Martin's prototype, eventually won the contract to produce the F-22. In the current fiscal year (FY2000) Congress has authorized the purchase of six F-22 aircraft for further development and testing before the F-22 reaches Initial Operating Capability (IOC) in 2005.[23] IOC means that the first operational squadron of F-22s will be available for use in conflicts worldwide. That's 20 years from the ATF concept to F-22 IOC, assuming that the F-22 reaches IOC on time.

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21 http://dmea.osd.mil/microelectronics_obsolescence.html

22 Lockheed-Martin Aeronautics Company, Fighter Programs. F-22 Raptor. http://www.lmtas.com/FighterPrograms/F22/index.html.

The F-15 and the F-16 were introduced in 1976 and 1979, respectively. These aircraft are still operational in 2000 and expected to remain operational for at least another decade. According to Lockheed-Martin Aeronautical Systems, the F-16 will remain operational until after 2020.[24] The F-22 is expected to last 30 to 35 years, conservatively.[25] The longer service lifetime for weapon systems means that each system spans an ever-increasing number of IC lifecycles, increasing the likelihood of DMS occurrences in current-use ICs.

This type of timetable for system development is significantly longer than the commercial world's timetables for product development and acquisition (See Figure 1). But those commercial developers are now the principal players in the IC market. According to the Defense Microelectronics Activity, long design time frames, compounded with extensive testing and collaboration across many functional areas and increasing service life extension programs, mean that "support requirements extend for 25 to 30 years, as opposed to the 4 to 7 year support requirements for commercial electronic systems."[26]

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23 F-22 Systems Program Office Briefing, "F-22 Avionics." Source: Mr. Ken Fehr, F-22 SPO DMS Program Manager.

24 Lockheed-Martin Aeronautics Company, Fighter Programs. F-16 Fighting Falcon: Status. http://www.lmtas.com/Fighter_Programs/F16/f16_status.html.

25 Interview, Mr. James Neely, 25 JAN 00.

26 Defense Microelectronics Activity website. http://dmea.osd.mil/microelectronics_obsolescence.html

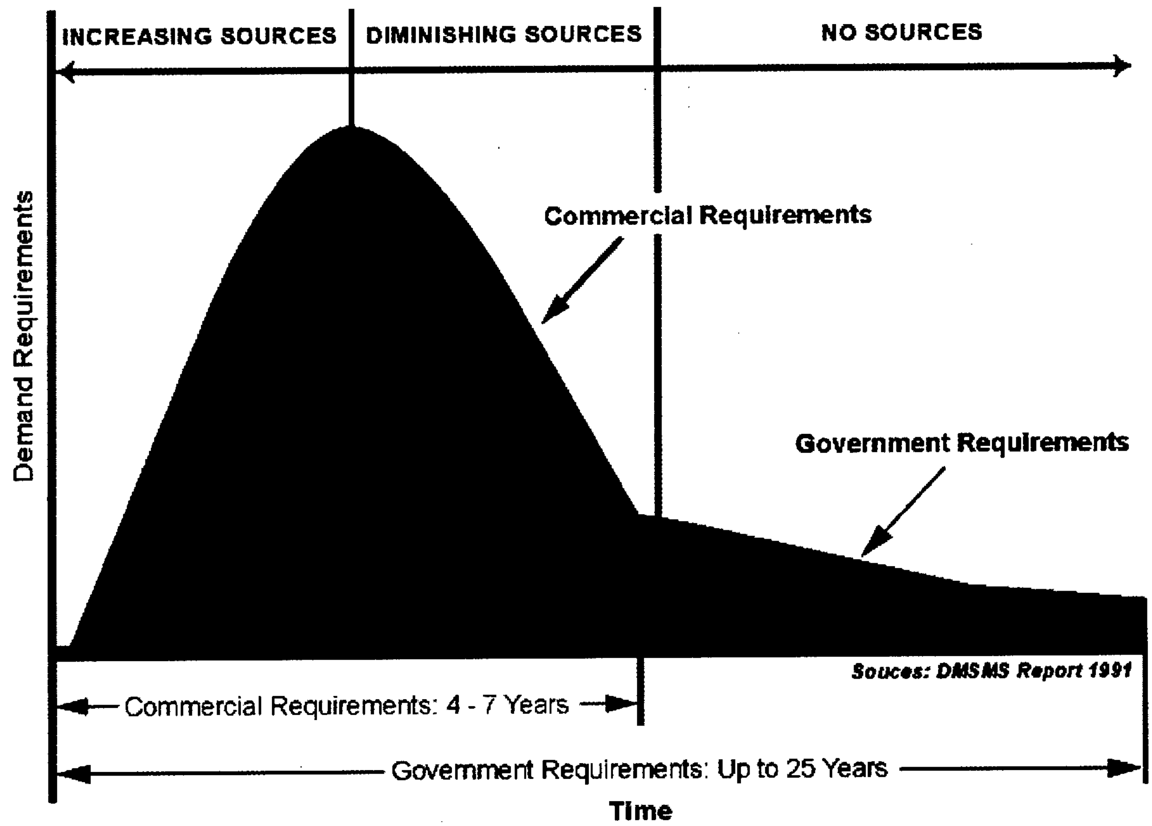

Figure 1: **Requirements Timelines**[27]

Fiscal austerity has contributed as well to the challenge in speeding up this timeline. The end of the Cold War brought about expectations of a peace dividend, meaning reduced defense expenditures. Real defense spending decreased in the immediate aftermath of the Cold War, but has remained relatively constant since that reduction. In the case of the F-22, Congressional scrutiny has been present throughout the program's lifespan. The climax of this scrutiny came in the summer of 1999, when, in the midst of the budget battle, the House Appropriations Committee voted to remove the $1.8 billion for the purchase of six F-22s in FY2000.[28] This vote was eventually overturned in the final budget. The constant public scrutiny involved in developing new weapon

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[27] Source: Defense Microelectronics Activity (DMEA). http://dmea.osd.mil/microelectronics_obsolescence.html

[28] Schneider, Gregg. "Red Hot Fighter, Trail of Deception." *The Baltimore Sun*, July 18, 1999, 1.

systems is an important factor in extending the timelines required for development and acquisition of operational Air Force weapon systems and adds a volatility to the relationship between the Air Force and its suppliers and contractors.

THE AIR FORCE RESPONSE TO THE IC CHALLENGE

The Air Force has developed a number of responses to DMS occurrences. Most of these responses deal with Problem (1), where an IC has already gone out of production and now AFMC must determine a method for keeping the weapon system "in business." This set of responses forms the bulk of the Air Force's current "toolbox" for supporting its aircraft in the face of supply base problems. This "toolbox" consists of many players and a complex environment. To maintain a tight focus in assessing the Air Force response, this analysis will focus on two weapon systems (F-16 and F-22) and four key players in the Air Force response to the IC challenge. They are:

- The F-16 Systems Program Office (SPO), Wright-Patterson Air Force Base, Ohio and the F-16 Air Logistics Center (ALC), Hill Air Force Base, Utah.
- The F-22 Systems Program Office (SPO), Wright-Patterson Air Force Base, Ohio.
- The Air Force Materiel Command Diminishing Manufacturing Source and Material Shortages Program Office (AFMC DMSMS Program or "Hub"), Wright-Patterson Air Force Base, Ohio.
- The Defense Microelectronics Activity (DMEA), McClellan Air Force Base, California.

THE STATUS QUO: PAINTING A PICTURE OF THE CURRENT SITUATION

The action surrounding ICs in the Air Force is intense and varied. Perhaps one of the most challenging aspects of this problem is simply getting a picture of what the Air Force as a whole is doing about this problem. This section attempts to explain current practices for responding to DMS in the F-16 and the F-22, with focus on four of the key players (organizations).

THE PLAYERS: KEY ORGANIZATIONS IN ADDRESSING THE F-16 AND F-22 IC SUPPLY CHAIN CHALLENGE

THE F-16 SYSTEM PROGRAM OFFICE (F-16 SPO) AND THE F-16 AIR LOGISTICS CENTER (F-16 ALC): SPOS DEVELOP, ALCS SUSTAIN

It is an unusual occurrence for one aircraft to have both a System Program Office (SPO) and an Air Logistics Center (ALC) for any significant period of that aircraft's life, but the F-16 is an example of this. Traditionally, Air Logistics Centers and Systems Program Offices follow a general pattern in their roles with respect to their particular weapon systems. Broadly, SPOs are responsible for development and ALCs for sustainment.

SPOs operate under Air Systems Command (ASC) and are charged with the development and testing of aircraft. The SPO works closely with the contractor throughout the development and testing phases of aircraft development. In this capacity, the SPO provides an Air Force voice in the development process. The SPO also gives the Air Force a body of people knowledgeable about many components of the weapon system and their development. The SPO also performs the important function of rating the contractor's performance, providing a contractor accountability mechanism.

Once the aircraft has matured through the development and testing phases and is ready for operational use – reaches Initial Operating Capability (IOC) – the sustainment function for that weapon system is taken over by an ALC. This phase of transferring the onus of aircraft logistical support from the SPO to the ALC is called the Program Management Responsibility Transfer (PMRT). Before PMRT, the SPO handles the development, testing, and sustainment functions for the weapon system, including new design and support functions. After PMRT, the ALC assumes responsibility for sustaining the aircraft. The ALC focuses more on sustainment functions and less on development. The F-16 DMS Program Manager estimated that the F-16 ALC spends about 85% of its resources on sustainment and about 15% on new development.[29] Air Logistics Centers provide for the "care and feeding" of the weapon system throughout the remainder of its lifetime.

Usually after an aircraft reaches IOC, the SPO is eliminated and the ALC assumes responsibility for the logistical support of that aircraft. The F-16 SPO was never eliminated, however, for a number of reasons. The F-16 SPO now performs both development and sustainment functions for the F-16, but splits these responsibilities with the ALC. The general focus of the SPO is to develop new systems for the aircraft – mostly avionics. The ALC generally focuses on sustaining the aircraft in its current state rather than upgrading its capabilities.

The F-16 SPO does not retain an organic DMS resolution capability. This capability is housed within the ALC. The SPO does rate the ALC however, on the performance of its sustainment mission.

[29] Most of the information in this paragraph, including this estimate, came from an interview with Mr. Michael Jackson, F-16 Air Logistics Center, Ogden, Utah, 20 MAR 2000.

An Air Logistics Center usually retains responsibility for the sustainment of more than one weapon system. The Ogden Air Logistics Center retains primary "depot repair, modification, and maintenance support"[30] responsibility for the USAF F-16 and foreign military sales (FMS) F-16s, the USAF, Navy/Marines and FMS C-130, and the USAF A-10. For each of these aircraft, the ALC will have a specific Supply Chain Manager (SCM) and accompanying staff charged with sustainment of that weapon system. Prior to January 1999, the F-16 ALC was owned by the F-16 SPO. However, the ALC no longer reports to the SPO; rather, there is a division of labor between the two organizations that support the F-16. This division of labor has been unclear and has blurred the lines of authority in the F-16 supply chain. The SCM at the ALC deals with the F-16 on a parts level, dealing with stock numbers and parts numbers – individual items. The weapon system manager at the SPO deals with the entire aircraft. These delineations do not always provide a clear picture of who is responsible for what pieces of the sustainment and development puzzle.

THE F-22 SYSTEM PROGRAM OFFICE (F-22 SPO)

The F-22 SPO currently retains responsibility *within* the Air Force for F-22 development and testing of all F-22 systems. It shares this responsibility with the prime contractor for the F-22, Lockheed-Martin. Like any SPO, the F-22 SPO performs an oversight function for the Air Force, rating Lockheed-Martin's performance in developing the F-22. By terms of the current contract for F-22 support, Lockheed-Martin shoulders much of the development and testing responsibility. This means that Lockheed-Martin helps shoulder the responsibility for DMS resolutions, partially relieving Air Force suppliers of this burden.

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30 Ogden Air Logistics Center Mission Statements, Aircraft Directorate (LA) Mission Statement. http://www.hill.af.mil/la/lasite/laweb/lamisn.htm

If the F-22 follows traditional practice for aircraft support, responsibility for F-22 sustainment will be transferred through PMRT to an F-22 ALC in 2005. 2005 is the year projected for the F-22 to reach IOC, with the first operational squadron likely at Langley Air Force Base, Virginia. The F-22 ALC will likely be at either Warner-Robins Air Force Base, Georgia, or at the Ogden Air Logistics Center.

Complicating the F-22 support picture, however, is the projected use of the CLS contract with Lockheed to provide for the bulk of logistical and sustainment needs over the next 15 to 20 years of F-22 operation. This means that the F-22 ALC will share responsibilities for F-22 support with Lockheed-Martin during this period. It is unclear at this point what specifically this division of labor will look like. According to the F-22 Avionics Program Briefing, 100% of the F-22 avionics support for the F-22 will come from Lockheed-Martin through 2009 or 2010.[31] In practice, however, the ALC will play a role in F-22 support that is unclear at this time.

The F-22 SPO retains a mix of redesign and upgrade authority despite Lockheed-Martin's apparent 100% responsibility. The budget for FY99 also provided the F-22 SPO with $80 million for dealing with DMS problems in the F-22[32] (for the structure of this funding, see the section "DMS Programs in the F-22"). This allows the F-22 SPO to retain an in-house DMS resolution and planning capability. Mr. Ken Fehr, part of the F-22 SPO Engineering Team, is the lead on this issue. The F-22 DMS program has developed a detailed plan for dealing with some of the DMS and

31 Source: F-22 SPO Briefing: "F-22 Avionics Program."

32 U.S. House of Representatives, Appropriations Committee: House Report 105-591, Department of Defense Appropriations Bill, 1999.

obsolescence issues that the IC challenge will pose for sustaining and upgrading the F-22 as it matures. These programs will be discussed in the section "DMS Programs in the F-22."

AIR FORCE MATERIEL COMMAND DIMINISHING MANUFACTURING SOURCES AND MATERIAL SHORTAGES (AFMC DMSMS) PROGRAM[33]

The only Air Force Materiel Command organization solely concerned with the DMS problem in USAF weapon systems is the Air Force Materiel Command Diminishing Manufacturing Sources and Material Shortages Program (AFMC DMSMS Program), also known as the DMSMS Hub or just "the Hub."

The AFMC DMSMS Program as it exists today is rooted in the 1994 flurry of requests from AFMC SPOs for help from the Hub in dealing with the DMS challenges they faced every day. Around this time, SPOs and ALCs began to experience explosions in DMS occurrences. As previously mentioned, the F-16 SPO alone went from 2 DMS cases in FY94 to over 600 in FY98.[34] The SPOs were receiving parts discontinuance notices or other DMS notifications and struggling with how to respond and keep their weapon systems flying. AFMC support personnel asked the Hub to provide some answers: what had been done in the past, what are the available options, and how can contracts be written to help resolve the DMS problem?

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[33] The information in this section about the AFMC DMSMS Program was obtained from two interviews with the DMSMS Program Technical Manager, Mr. James Neely, and from the DMSMS Case Resolution Guide (15 July 1998) and the Assessment of the AFMC DMSMS Program (16 October 1995).

[34] Interview, Mr. Michael Jackson, F-16 ALC, Ogden, Utah, 15 MAR 00. Air Force Lieutenant Colonel Vince Adamski actually submitted a letter to Headquarters, Air Force Materiel Command detailing this specific explosion of DMS cases and requesting some additional DMS funding and centralization. The letter, sent out under his commander's signature – as an Air Combat Command member -- was never acted on.

After this concerted request for help, the Hub first began to take on many of the roles that it now performs for AFMC. The first step in the Hub's evolution was the *1995 Assessment of the AFMC DMSMS Program.* This assessment determined that the Hub should take a more active stance towards DMS. It also recognized the need for automation in tracking and solving DMS problems, as well as the need for the Hub to do more than just relay DMS notifications but to also provide some possible solutions for SPO and ALC personnel. The need for these solutions resulted in the development of the *Case Resolution Guide*, last published in July of 1998, with a new edition to be published this year. This guide provides AFMC logistics and support personnel with a reference for resolving DMS cases.

Since the 1995 Assessment, the Hub has assumed a number of different functions for Air Force Materiel Command in dealing with the DMS problem. According to Mr. James Neely, the DMSMS Program Office Technical Manager, the functions of the Hub can be broken down into three main missions. These missions are to provide Air Force Materiel Command with: (1) Training, (2) Information, and (3) Tools.

Training. The Hub is responsible for assessing the training needs of AFMC's support personnel. The Hub holds training events to educate personnel about the vanishing supplier problem and give them some tools and guidance for dealing with the problem in their weapon systems. One difficult part of this training function is determining how to present practices for dealing with DMS problems to AFMC personnel whose weapon systems are affected by the problem. This is a question of designing course work for AFMC personnel to understand the DMS problem. The Hub

performs these roles by developing information toolkits and arranging for training sessions for affected weapon system managers.

The DMSMS Program also attempts to provide DMS-affected personnel with training for using the analytic tools the Hub operates and maintains as part of its information role. The primary tool for the Hub in this analytic role is the Avionics Components Obsolescence Management Database (AVCOM Database). This computer tool can perform analysis on a number of different weapon systems and provide parts and usership information for managers seeking solutions to DMS problems.

Information. The DMS Program is called the Hub principally because of this information role. The Hub is AFMC's central receptor of product discontinuance notices and distributes that information to the appropriate AFMC personnel – the SPOs, Item Managers, Program Managers, Systems Engineers, and other affected parties. The Hub does this by performing an analysis of which systems are affected by the DMS part, using the AVCOM database and other tools – when these databases are populated with the appropriate data. They then prepare a worksheet for the ALCs and SPOs with the parts-use information. In this way, the Hub helps with some of the preliminary research necessary for dealing with the DMS part.

In this information role, the *AFMC DMSMS Case Resolution Guide* provides a comprehensive list of tools for dealing with DMS to working-level personnel in the SPOs and ALCs. The *Case Resolution Guide* for 200 will also include a compilation of key language from existing contracts that have been effective in dealing with DMS issues.

The Hub also contributes an awareness dimension to AFMC's DMS challenge. Hub personnel perform a constant information-gathering task, reviewing literature and attending conferences and

other events relevant to the DMS problem. The personnel in the SPOs and the ALCs have little time or funding for performing this function, so Hub personnel gather and screen the information for dissemination to the relevant parties within AFMC.

Tools. Hub personnel operate and maintain the AVCOM composite avionics database. It is the principal tool that the Hub has for performing analysis. AVCOM allows for prioritization of the most important parts replacements within a weapon system, helping inform the questions: what needs to be upgraded, and what upgrades can be afforded? This database currently includes a large body of information on the F-15, JSTARS, AC-130, and B-1 weapon systems. At this point, the AVCOM database does not contain any significant body of data for the F-16 or F-22 weapon systems, or many other weapon systems. Attempts to populate the API with F-16 information have encountered funding and manpower problems. It is unclear why the API database still lacks F-22 information, although its status as pre-IOC may be a factor. This report recommends that completion of the API program be the initial step toward a more efficient DMS resolution capability.

Finally, the Hub is also responsible for supporting decision-makers at the SPOs and ALCs when they are confronted with a DMS challenge. The Hub tries to assess the impact of the DMS problem in each affected system and support the decision-maker in determining the appropriate avenue for resolving each case of DMS; the criteria used in evaluating the options for DMS resolution are: *cost*, impact to the system, and feasibility of upgrade or redesign.

DEPARTMENT OF DEFENSE INITIATIVE: DEFENSE MICROELECTRONICS ACTIVITY (DMEA)

The Defense Microelectronics Activity, located at McClellan Air Force Base, California, is charged with the following mission: "to leverage the capabilities and payoffs of advanced technology to solve operational problems in existing weapon systems, increase operational capabilities, reduce operation and support (O&S) costs, and reduce the effects of diminishing manufacturing sources (DMS)."[35]

DMEA is the DoD "executive agent" for DMSMS problems. This means that they are responsible for information flow, training, and consultation – but cannot choose a course of action for resolving a DMSMS issue and enforce that action. DMEA's involvement in specific weapons programs has generally been at the request of the SPO involved with that weapon system.

DMEA "responds to obsolete parts requests when no solution from any other source is available. Provides engineering solutions (e.g. reverse engineering) to DMSMS problems upon request from various Air Force, DoD and Federal Agencies. Their capabilities include IC Design & Development, Technology Assessment, Feasibility & Data Analysis, CAD/CAE, Reverse Engineering, and Component Testing."[36] DMEA is a resource for providing engineering knowledge and talent when absolutely no solution exists but to reverse engineer the DMS IC or produce another IC specifically for the DMS need. DMEA's engineers can essentially become a government IC production shop when needed, but this is resource-costly in both dollars and time.

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[35] http://dmea.osd.mil/mission.html

[36] AFMC DMSMS Program Case Resolution Guide, 15 July 1998, 33.

DMEA provides information and tools for different programs facing DMS not just within a particular service, but across all DoD. The purpose is to coordinate DoD-wide solutions to these problems, leveraging the power of a joint response.

WHAT HAPPENS WHEN AN INTEGRATED CIRCUIT GOES DMS?

Now that some of the players in this complex structure have been identified, this section will attempt to step through a general picture of the Air Force response to an IC DMS occurrence.

BACKGROUND INFORMATION: FOCAL POINTS AND ANALYTIC TOOLS

Focal Points. Generally the Item Managers, Program Managers, or Systems Engineers within aircraft SPOs or the ALC are the DMSMS Focal Point – meaning they are the decision-maker for response to DMS occurrence. Focal Points can utilize the Hub and DMEA as resources to assist in these decisions, or call on DMEA to assist with IC production in the direst of circumstances. Other similar resources exist at the Defense Logistics Agency, in the other military services, and within contractor organizations.

Analytic Tools. AVCOM is the database that the DMSMS Program uses to identify parts users, cross-reference equivalent parts, and help prioritize DMS solutions. TACTRAC is the database used in the F-16 ALC and SPO and the F-22 SPO. TACTRAC is a commercially supported database that the Air Force purchases from a contractor – TACTech, Inc. TACTRAC provides these offices with a predictive tool for dealing with DMS and obsolescence by using modeling techniques to forecast future parts demand levels and IC market reactions. TACTRAC is a Web-based tool that has wide

commercial and military applications, with a focus on aerospace industry (See www.tactech.com). TACTRAC is widely praised by personnel in both the F-16 and F-22 programs for its value in predicting DMS occurrences, obsolescence, and market dynamics.

THE DMS RESOLUTION PROCESS

IC Supplier Terminates Production. The first step in the DMS process is for an IC supplier to determine that production of the IC in question is no longer profitable or viable. At this point, the IC has "gone DMS" even though the Air Force may not realize it.

Notification or Identification of a Part as DMS. When manufacturers determine that they will cease production of an IC, it becomes a DMS occurrence. There are a number of ways in which the Air Force support community discovers that an item has become DMS. One method is through manufacturer-published notices of the part discontinuance. See product discontinuance notice from Motorola attached as an example (Appendix A).

However, the Air Force is sometimes not aware of the problem until an Air Force supply manager discovers the DMS occurrence through an unsuccessful attempt to purchase the item no longer in production. When this occurs, the affected party takes steps to disseminate this information – such as contacting the AFMC DMSMS Program Office, the Defense Supply Center Columbus (DSCC), the Government-Industry Data Exchange Program, or others. The information is then generally distributed to relevant personnel in the form of a DMSMS alert. Alerts may come from a variety of sources, including:[37]

[37] Source: AFMC DMSMS Program Case Resolution Guide, 15 July 1998, 2.

- Part Manufacturers and Original Equipment Manufacturers (OEMs)
- Defense Supply Center, Columbus (DSCC)
- Government-Industry Data Exchange Program (GIDEP)
- AFMC DMSMS Program Manager (Hub)
- Government Procurement/Repair Activities
- Military Parts Control Advisory Group
- Discontinuance Notice Alert Bulletin Board System
- Stock Control Clerks
- System Engineering Community

Warning/Notice Sent Out. After a part has been identified and a primary notification has been sent to a central information source, the notice is sent to relevant parts managers and support personnel for affected weapon systems. When the Hub or other information repositories (listed above) disseminate this information, they use databases like AVCOM or other tools, combined with personal knowledge of the process, to convey the information to the affected personnel. This step is extremely important because it forces the information holder to research what systems use the affected part and who manages the part.

Scoping the Problem. The next step is for the Focal Points in each of the affected weapon systems to determine what systems on their airframe are affected and to determine the magnitude of that impact. The Hub can help with this analysis, as can trained personnel within the SPOs/ALCs, through the use of databases like AVCOM or TACTRAC.

Options Analysis. When the manager for a specific IC is faced with the DMS challenge, he/she will work through a worksheet that details specific options for resolving the DMS case (See Appendix B). The options that affected program managers have to choose from are detailed below:

DMSMS Case Resolution Analysis Worksheet Options[38]

- Aftermarket Manufacturers (Alternate Source): "A manufacturer that buys obsolete production lines to maintain item production, or a supplier that buys quantities of parts going obsolete and stores them for future resale."[39] Aftermarket purchases are often extremely expensive on a per-IC basis.[40]

- Substitution: "The use of a similar item with an acceptable number of design differences that will not degrade the performance of the equipment."[41]

- Redefining Requirement to Accept Commercial Item: This option means the Focal Point examines whether the system could use a commercial-off-the-shelf (COTS) part to provide the same capability as the DMS part. Other considerations might

[38] DMSMS Case Resolution Analysis Worksheet. Source: F-16 Air Logistics Center, Mr. Michael Jackson.

[39] AFMC DMSMS Program, Case Resolution Guide, 15 July 1998, xiii.

[40] Interview, Mr. James Neely, 25 JAN 00.

[41] AFMC DMSMS Program, Case Resolution Guide, 15 July 1998, xiv.

include a necessity to rewrite software programs to interface with the COTS part. Both military and industry engineers agree, however, that many military and aerospace platforms do not need components that meet traditional Military Specifications standards for environmental conditions.

- Emulation: "The process of developing form, fit, and function replacements for obsolete microcircuits using . . . state of the art materiel design and processing techniques."[42]

- Life-of-Type (LOT) Buy: "The purchase of enough of an obsolete item to meet the projected demands of the supported equipment for the rest of its operational lifetime . . . the procurement quantity shall be based upon demand or engineering estimates of mortality sufficient to support the applicable equipment until phased out."[43]

- Developing New Source

- Reclamation: "The use of items found in equipment beyond economical repair, at repair facilities, within deactivated or decommissioned units, or removed and stored due to modernization programs."[44] This is also called cannibalization. This is a de facto occurrence on nearly all Air Force flight lines, regardless of the support community's awareness that the part is DMS or obsolete.

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[42] Ibid., xiii.

[43] Ibid., xiv.

- Redesign: "Designing a new item to replace an item that is obsolete or contains obsolete components."[45] Often when the affected part is an IC this means that the larger structure the IC operates within (card, board) is redesigned.

- Contractor Maintained Inventory

- Production Warranty

- Reverse Engineering: "The process of developing an exact replica of an item by using technical data, disassembled and analyzed copies of the original part and test data."[46] This is one of the specialties that DMEA provides in dire situations.

DMS Focal Points must balance a set of priorities in determining which DMS resolution option to pursue. Their priorities: (1) ensure the supply stream for the affected system remains intact, (2) minimize the cost of the solution, and (3) determine when upgrades, redesigns, or other options for getting away from the DMS part are most appropriate. Cost dominates these concerns.

Resolution/Implementation. After determining the appropriate action for resolving the DMS occurrence, the DMSMS Focal Point must follow-through to correct the supply chain problem. Generally the decision is made within the SPO or ALC; the SPO during aircraft development, the ALC after PMRT.[47] Then DSCC or the Air Force Item Manager carries out implementation of

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[44] Ibid.

[45] Ibid.

[46] AFMC DMSMS Program, Case Resolution Guide, 15 July 1998, xiv.

[47] The F-16 is an exception to this rule, because the F-16 program still has a SPO and an ALC. The division of labor between these organizations is unclear both to the researcher and to many within these organizations.

DMS resolution option. Sometimes Air Force System Engineers trump this process and elect to implement a different resolution. For example, System Engineers may determine the obsolescence of some particular ICs to be critical to operation of the system, and redesign the IC or the larger systems it is part of as a solution to the DMS problem. Sometimes these Systems Engineering interventions are based on information that only Systems Engineers possess or understand.

Having put forth a general framework for understanding the actors, roles, and general "rules of the game" for resolving DMS and obsolescence problems, section attempts to describe some current efforts in the F-16 and F-22 programs to deal with DMS occurrences.

DMS PROGRAMS IN THE USAF F-16

AN INTRODUCTION TO THE F-16[48]

The Air Force and the United States have benefited from the versatile General Dynamics (now Lockheed-Martin) F-16 Fighting Falcon for well over two decades. According to the official Air Force factsheet, "[t]he F-16 Fighting Falcon is a compact, multirole fighter aircraft. It is highly maneuverable and has proven itself in air-to-air combat and air-to-surface attack. It provides a relatively low-cost, high-performance weapon system for the United States and allied nations."[49]

The first successful flight test of the F-16 occurred in 1976, and the aircraft reached Initial Operating Capability (IOC) in 1979 at Hill Air Force Base, Utah. The F-16 began as the

[48] The information in this section was obtained from the Official Air Force F-16 Website: http://www.af.mil/news/factsheets/F_16_Fighting_Falcon.html

[49] F-16 Fighting Falcon: Mission. http://www.af.mil/news/factsheets/F_16_Fighting_Falcon.html

multipurpose partner to the F-15 air superiority fighter. This meant that the F-15 would perform the majority of the air-to-air combat while the F-16 would perform air-to-air and air-to-ground missions, both roles in which the F-16 has proven itself. The initial models of the F-16, the A (single-seat) and B (two-seat) models, were built under an international consortium of nations: the United States, Belgium, Denmark, the Netherlands, and Norway. Parts of the aircraft were manufactured in each of these nations, with final assembly locations in the US, Belgium, and the Netherlands. Some of the benefits touted for this multinational consortium production process were: a common-use aircraft for five NATO nations, sharing of technology among allies, and increased supply and availability of parts for the European F-16 owners. The F-16C and D models have since replaced nearly all A and B models in the USAF, with the exception of some Air National Guard and Air Force Reserve flying units.

Perhaps even more important than the A/B/C/D designation is the block number that identifies an F-16's enhancements. As time has passed over the life of the F-16 (or any other Air Force fighter), the aircraft have been upgraded with newer avionics systems, weapons, and propulsion systems. The upgrades in the F-16 have added combat capability. Block 10 F-16s were upgraded to Block 15, then Block 20, and so on, to the most recent Block 60 F-16s rolling off the assembly line today. The initial F-16 capabilities in the Block 10 model have been completely transcended in the Block 60. Since its inception as a mutlirole, daytime fighter, avionics upgrades have transformed the Block 50 F-16 into an all-weather, night-mission capable, precision strike aircraft with highly advanced radar systems. The Block 50 has assumed new missions because of its added capabilities, including the famed Suppression of Enemy Air Defenses mission – also known as the "Wild Weasel" mission – to destroy enemy surface-to-air missile sites.

The F-16 remains in production, although the USAF currently only buys between 5 and 9 Falcons each year.[50] Foreign Military Sales now form the major source of revenue for Lockheed-Martin and allow the profitable operation of the production line to continue.

DMS PROGRAMS IN THE F-16

Initially, the F-16 team had no idea that it would have to deal with DMS and obsolescence.[51] This is no longer the case. Currently Mr. Michael Jackson of the F-16 ALC manages DMS problems in the F-16.

As Mr. Jackson discovered when he attempted to research data on the parts within the F-16, nobody knows exactly how many parts are in the F-16 or exactly how many ICs are in the F-16. Because of the aircraft's origin in an international consortium, tracing the origin of many parts in these aircraft is extremely difficult.[52] F-16 products come from all over the world, and often follow a complex purchasing chain before finally reaching the aircraft. The generally accredited estimate for parts in the F-16 is about 10.5 million. Avionics systems comprise approximately half of these parts.[53] The Defense Logistics Agency manages most of the ICs in the F-16. These circuits are housed predominantly in the aircraft's avionics systems.

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50 Interview, Mr. Michael Jackson, F-16 ALC, Ogden, UT, 15 MAR 00.

51 Interview, Mr. Michael Jackson, F-16 ALC, Ogden, UT, 20 MAR 00.

52 Interview, Mr. Mike Jackson, F-16 Air Logistics Center, Hill Air Force Base, UT, 15 MAR 00.

53 Interview, Mr. Michael Jackson, F-16 Air Logistics Center, Ogden, UT, 20 MAR 00.

There is little information about the F-16 in the Hub's AVCOM database. The F-16 ALC and SPO have indicated that lack of funding has prevented them from populating this database with the F-16 data.[54] However, the F-16 ALC and SPO have developed a number of different sustainment and upgrade programs.

One Program that the F-16 SPO has developed is the Common Configuration Implementation Program (CCIP). This Program is designed to provide upgraded or replaced avionics subsystems to the Block 40, 42, 50, and 52 F-16s in the USAF. The following diagram below (Figure 2) details the affected systems. While CCIP is an upgrade program, it has recognized the DMS problem and incorporated some preventive actions, such as relying on the contractor for DMS resolutions in the upgraded systems.

[54] Interview, Mr. James Neely, AFMC DMSMS Program Manager, 25 JAN 00.

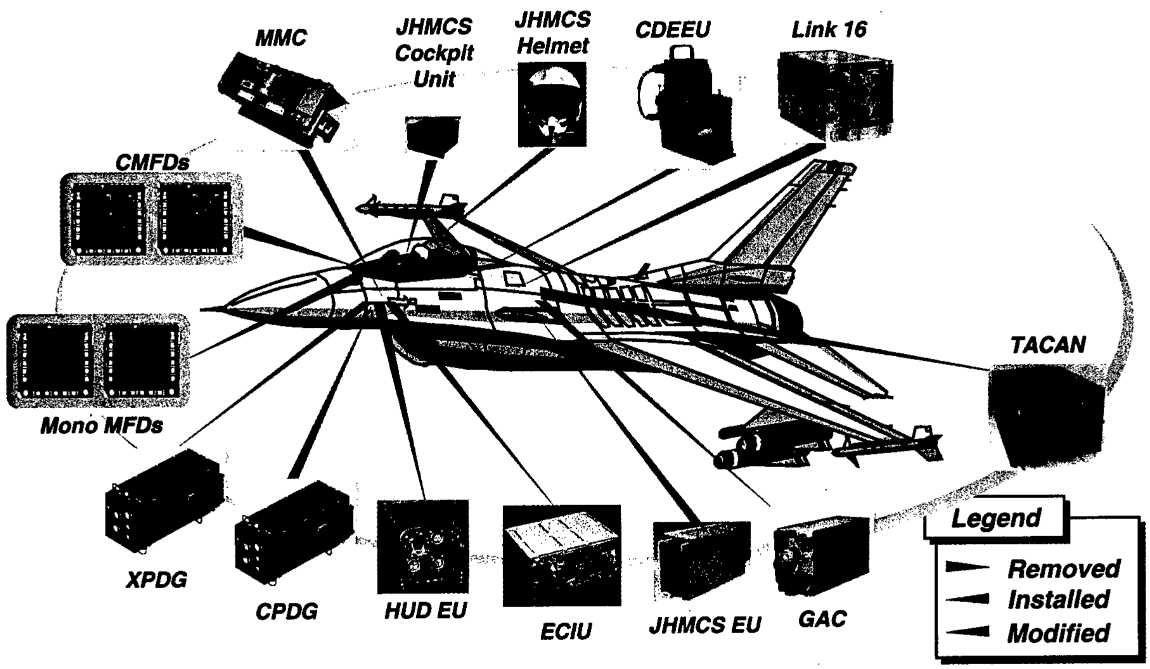

Figure 2: Avionics Systems on the F-16 Affected by the Common Configuration Implementation Program[55]

The F-16 ALC also recently signed a contract with Lockheed-Martin for a program called Combined Lifetime Support (CLTS). According to the terms of this contract, Lockheed-Martin assumes all responsibility for DMS management and resolution in non-CCIP avionics systems – although AFMC personnel will nonetheless be a part of the teams that resolve these occurrences.[56] Under the CCIP program, DMS resolutions will generally come under four categories:

- Last/Lifetime Buys

55 Source: Common Configuration Implementation Program Briefing, Mr. John Joseph, F-16 Systems Program Office, Wright-Patterson Air Force Base, OH.

56 Although the contract stipulates that Lockheed-Martin assume all DMS responsibility, the ALC DMS Manager still shoulders much of this burden. The exact division is unclear.

- Parts Substitution

- Component Redesign

- Cloning

Each of these measures is reactive in nature, dealing with a DMS case when it "pops up." These programs also demonstrate the USAF trend to transfer responsibility for DMS problem resolution to the contractor.

By law, 50% of all aircraft maintenance has to go through military-owned depots, like the F-16 ALC. This means that while the contractor may be charged with solving the problem, ALC personnel will often still execute the DMS resolution on many of the affected aircraft – meaning their personnel will be part of DMS resolution teams and will actually replace the affected parts on many aircraft.

The approaches taken to DMS resolution and management in the F-16 have been reactive, but they have managed to ensure a continuous flow of materiel for sustainment of the "backbone" of the US fighter force. Yet, the generally successful efforts to resolve DMS occurrences so far will not provide a powerful enough tool to handle the future of the DMS problem. Future changes in IC technology will render many of the current approaches to DMS resolution obsolete; future solutions will require structural changes and reprioritization of DMS as a problem.

INTRODUCTION TO THE F-22.

The idea for what is now the F-22 began in the late 1970s within the Air Force, where concepts were explored for a follow-on fighter to the USAF's newest air superiority aircraft, the F-15. In 1985 the Air Force officially sanctioned the idea for this new tactical fighter. This official sponsorship led to the Advanced Tactical Fighter (ATF) competition, a duel between the YF-22 prototype and the YF-23 prototype. Lockheed's YF-22 eventually won this duel for the Air Force's newest fighter in 1991, when the Air Force awarded the program the $9.55 billion contract for Engineering and Manufacturing Development of the F-22. This contract charged Boeing and Lockheed Martin with the design of the aircraft, production of tooling, and construction and testing of "nine flightworthy aircraft and two ground test aircraft."[57]

There are a number of complex avionics systems on the F-22. Already these systems are experiencing problems with IC DMS and obsolescence. For a non-engineer, a simple list of F-22 avionics systems would include:[58]

57 The background information for the F-22 in this paragraph came from Lockheed-Martin's Fighter Programs F-22 Website, http://www.lmtas.com/FighterPrograms/F22/index.html, and Air Force Link's Official F-22 Raptor History. http://www.af.mil/lib/airpower/history.html.

58 This F-22 avionics information has been simplified from a briefing put together by the F-22 SPO, Mr. Ken Fehr, entitled: "F-22 Avionics Program."

- Electronic Warfare Systems: Threat Warning, Radar, Missile, Threat Countermeasures, Infared Countermeasures (Flares), Chaff, Embedded LO Apertures, and Common Integrated Processor Signal / Data Processing.

- Stores Management: Air-to-air and air-to-ground weapons control, Expendables control.

- Common Integrated Processors: Integrated System/Sensor Operations & Control, High Capacity Memory & Throughput, Multiple Flexible Bus Configuration, Fault Isolation & Fault Tolerant, Fiber Optic Connections Between Processors and Sensors.

- Inertial Reference System: Global Positioning System (GPS) and other aids to navigation.

- Controls & Displays: Color Liquid Crystal Displays, Heads-Up Display (HUD), Sunlight & Night Vision Compatible, Airborne Videotape Recorder.

- Communication, Navigation, and Identification (CNI): Secure Voice and Data Links, GPS, Tactical Aid to Navigation System (TACAN), Identify Friend or Foe Interrogator and Transmitter.

- Radar: Active Electronically Scanned Array, Multi-mode.

DMS PROGRAMS IN THE F-22

For many of these avionics systems, SPO personnel have already developed detailed planned upgrades for the future. These block upgrades would take place every 2-3 years, replacing or upgrading specific avionics systems with redesigned or upgraded systems. The F-22 SPO's briefing "F-22 Avionics Program," contains a series of technical documents that display the upgrades for

each lot of F-22s as they are produced and purchased over time. DMS funding begins "protecting" the 6 F-22 test aircraft purchased in FY 2000. After this, DMS funding is provided for "pop-ups" in the initial group of operational F-22s purchased, to a cap (the $80 million allocated by the House Appropriations Committee). The funding for DMS cases in the first group of operational aircraft purchased (a total of 50 F-22s, purchased 2001-2005) will also have to cover the second major group of operational F-22s (a total of 180 additional, purchased 2004-2009). Currently there is no funding protection for the third group, scheduled to become operational in years 2009-2013.[59]

The F-22 Program has implemented a pilot program for buying commercial ICs from TRW Corporation's automotive production line and "ruggedizing" those ICs to Air Force standards. The program is called Military Products from Commercial Lines (MPCL). In MPCL, TRW's state-of-the-art production facilities are utilized, the ICs are purchased at market prices, and the Air Force contracts the labor to "ruggedize" the ICs for use in the F-22. MPCL shows promise in achieving cost savings and, prospectively, battling the DMS and obsolescence problems. According to the SPO, the MPCL program has achieved 30-50% cost reductions in F-22 electronics modules.[60]

Federal spending guidelines have complicated efforts in the F-22 program to develop answers to the DMS and obsolescence problems. Because of the yearly budgeting process, F-22 contracts must be done on a yearly basis. This leaves contractors uncertain of future Air Force business. The political pulling and hauling in Washington over the F-22 has added to this uncertainty, with the Appropriations Committee voting in the summer of 1999 to remove funding for the F-22. This

59 F-22 SPO Briefing, "F-22 Avionics Support Program." Source: Mr. Ken Fehr, F-22 SPO DMS Program Manager.

60 F-22 SPO Briefing: "F-22 COTS Program." Mr. Ken Fehr, F-22 SPO, Wright-Patterson Air Force Base, Ohio.

would have been a major setback for Lockheed-Martin and the other contractors on the F-22 program, eliminating $1.8 billion from the program. This volatility makes it difficult to establish long-term relationships with contractors, which compounds the DMS and obsolescence problems. Multi-year contracts might have the potential to establish stronger incentives for IC manufacturers to keep production lines open longer, but given the Air Force market share this effect may be small.

The current Air Force support plan for the F-22 is called Contractor Logistics Support (CLS). Under this plan, the prime contractor (Lockheed-Martin) would be responsible for support to all F-22 avionics systems. The plan is for the contract to last 15 to 20 years. However, the F-22 is expected to last 30-35 years.[61] As mentioned previously, this may not present a serious problem if contract renegotiations keep the responsibility for DMS resolutions in the hand of the contractor. If not, however, this lack of data will make dealing with DMS occurrences much more complex.

CRITIQUES OF CURRENT PRACTICES

POSITIVE DEVELOPMENTS

Three major developments within this discussion are very positive steps that AFMC has taken towards resolving DMS occurrences. These developments are: using the TACTRAC database when possible, utilizing COTS ICs and "ruggedizing" them, and shifting responsibility for DMS resolutions to contractors.

The F-22 program has used the TACTRAC database as a tool for determining which ICs to place in its upgrades. This is a major step forward for DMS resolution that should bear fruit as time passes on the F-22 airframe. The use of TACTRAC demonstrates that within the F-22 SPO there is

61 Interview, Mr. James Neely, AFMC DMSMS Program Technical Manager, 25 JAN 00.

a clear understanding of the parts involved in at least some systems, which allows them to utilize predictive tools for choosing DMS-resistant ICs.

The F-22 SPO also has capitalized on industry expertise to prevent DMS problems. In the Military Products from Commercial Lines Program (MPCL), the F-22 SPO has demonstrated the ability to combine proactive DMS actions with cost savings. Buying these COTS ICs has provided significant cost reductions while also adding a layer of DMS-resistance to the IC due to its wide commercial customer base in the automotive industry.

Shifting DMS resolution responsibility to contractors is a positive trend as well in some aspects. This process can help prevent budget battles over limited AF resources, place the DMS resolution burden within a more experienced organization, and accelerate decision-making concerning DMS occurrences. The downside to this trend is that it prevents AFMC from developing in-house expertise to deal with DMS across its many weapon systems. Perhaps the contracts for the F-16 and F-22 can provide for Lockheed-Martin to resolve DMS occurrences, but in the many other USAF airframes this may not be the case. In that situation, AFMC expertise for dealing with DMS will be invaluable.

NEGATIVE PRACTICES

LACK OF INFORMATION/DATA MANAGEMENT PROBLEM

The most frustrating aspect of dealing with DMS occurrences is the wasteful, reactive stance that Air Force DMS problem-solvers generally are forced to employ. The driving force behind this ad hoc reaction is a lack of information about our own Air Force weapon systems. As stated above, at

the turn of the new millennium, there is no person or system in the Air Force that can identify every part in the F-16. This problem has been recognized for some time.

In 1983, the Office of the Secretary of Defense mandated the execution of the Applications, Programs, and Indentures Initiative (API) across DoD. The goal of this program was to catalog all the parts in every weapon system that DoD owns and maintains in a central database. The Office of the Secretary of Defense called this mandate Operation CORAL VERIFY. OSD accurately diagnosed this data management problem in 1983 but the program has not been executed.

API sought to record exactly the parts in systems, replacement and mortality rates for those parts, and at what level those parts could be replaced – meaning, for ICs, on the flightline or in maintenance shops or depots. When dealing with the DMS and obsolescence challenges in the F-16, Mr. Michael Jackson of the Ogden Air Logistics Center discovered that in 1997 the API database still had not been populated with any F-16 data.[62] In 1997, Mr. Jackson hired a contractor to begin populating the database, but was forced to discontinue the contract because of funding constraints. As of the time of publication of this document, only about 275,000 of the 10.5 million parts in the F-16 have been cataloged in the API database.[63]

Why has the API effort, recognized as an important objective since 1983 (at least) still not been completed over 15 years later? The low priority given the API program has been reflected in its sporadic funding. This resource constraint has prevented the ALCs and SPOs from putting the work out to contractors. Equipment Specialists and SPO/ALC personnel have argued that they do

62 Interview, Mr. Michael Jackson, F-16 ALC, 15 MAR 00.

63 The information about the F-16 API database status was obtained in a 20 MAR 00 interview with Mr. Michael Jackson, F-16 ALC, Ogden, Utah.

not have time for this duty. Also, top-level support for the program has been volatile, due to the difficult prioritization of funding that must take place across DoD.

An important link exists between the API program and developing descriptive and predictive tools for Air Force DMS managers. Finding out what parts exist in Air Force systems is the critical first step in describing or predicting which parts will become obsolete or DMS. Populating the API program with data allows DMS Managers to transfer this data to AFMC's analytic tools, like AVCOM or TACTRAC. These tools can provide important descriptive information (AVCOM) and some prescriptive information (TACTRAC), but they must have the parts data from API to perform these functions. The ability to forecast DMS occurrences with some degree of accuracy is possible and would enable DMS Managers and Focal Points to plan and to program for DMS in their weapon systems This would save time, money, and improve aircraft performance.

The data management problem is also present in current contracts for support of both the F-22 and the F-16.

The F-22's planned CLS contract does not provide for the Air Force to purchase or obtain data about DMS, obsolescence, replacement rates, mortality rates, sourcing, or other data. This contract, still not finalized, will most likely last for 15 to 20 years. In light of the increasing lifespan of Air Force aircraft, this contract will not last for the entirety of the aircraft's service life. A similar contract for support on the F-16 would have expired in 1994 or 1999 (dating the contract life from IOC in 1979); for the F-15, the contract would have expired in 1991 or 1996. This means that when the Air Force support structure must resume operational sustainment of the aircraft, at its more mature and therefore DMS- and obsolescence-prone age of contract signing plus 15 or 20 years, it

will not have extremely important data about the history or present status of the aircraft. If properly managed, this data could provide the Air Force support community with the capability for predictive, proactive management of DMS and obsolescence. But if CLS remains as planned, the Air Force support community will be given an aging F-22 to support in 2020 or 2025 without detailed knowledge of the aircraft's system's history and present status.

Similarly, in the F-16 Common Configuration Implementation Program (CCIP) for avionics upgrade (See Figure 2) the Data Management problem has been shifted to the contractor (Lockheed-Martin). But the Air Force has not arranged to obtain this data when the Air Force resumes support of the CCIP avionics systems – if the Air Force does resume support of those systems.

This problem has also been part of the traditional PMRT transition between the SPO and the ALC. Because of separate budget concerns, SPOs put aircraft through development and testing phases without buying the data on avionics systems in that aircraft. The SPO objective is to develop the new fighter on time and under budget, providing them no incentive to purchase data that will not benefit the SPO after PMRT.

There is an important caveat to these concerns, however. If later contracts provide for Lockheed-Martin's continued responsibility for DMS over the life of the aircraft, then this potential problem could never arise. Re-negotiating later contracts for DMS resolutions would provide a method to keep the responsibility in the hands of the organization with the data.

NO UNIFIED DMS RESOLUTION ORGANIZATION

Organizationally, the Air Force approach to DMS is not managed by a central agency or knowledgeable body but is handled for each weapon system, and resources are drawn from that weapon system's budget to handle DMS. A unified DMS resolution effort could provide more than simply an information clearinghouse; it could perform analysis across weapon systems to consolidate DMS resolution efforts, distribute funding based on need, and remove the incentive for SPOs, ALCs, or contractors to ignore this issue as a short-term cost saver.

LACK OF CLARITY WITHIN THE AIR FORCE CONCERNING DMS RESPONSIBILITIES

The complex process involved in identifying a DMS integrated circuit, transmitting that information to the appropriate party, and achieving a DMS resolution is further muddied by the difficulty in determining which organization is responsible for that specific system. In the F-16 program especially, the confused relationship between the SPO and the ALC has caused problems in determining responsibilities for DMS resolution.

Many answers sought in this research were never found because of the lack of clarity within the responsible organizations. This is partly due to the difficulty in deciphering many of the acronyms, program names, and engineering language that outsiders (like this researcher) encounter. But this is also an issue of clarity within the organizations. The best answer to this problem lies in creating one responsible body for DMS resolution – a DMS "Hub" that has authority to prioritize and execute solutions.

DMS HAS RECEIVED LOW PRIORITY

The budget resources used for combating and resolving DMS problems within SPOs and ALCs currently are derived from those organizations' overall budgets. All weapon system support dollars currently must be approved by Air Combat Command, the "operator community," or customer, for these weapon systems. Air Combat Command leadership has been resistant to budget increases for dealing with DMS and obsolescence issues. Nonetheless, DMS is an accelerating problem and has the potential to threaten the Air Force's policy utility in future conflicts. Rethinking DMS' priority within the budget structure can help prevent future breaks in the IC supply chain that could ground aircraft.

A "smart" DMS strategy could also provide savings in the Air Force budget. According to the AFMC DMSMS program, DMS problems will have cost the Air Force at least $2.9 billion in redesign costs alone between 1994 and 2000.[64] Preventive planning could prevent many of these costs by incorporating upgrades at more appropriate times, reducing redesign costs, and eliminating some DMS occurrences completely.

Budgeting properly for dealing with these concerns will require increased funding from current levels, yet this will provide net savings in the long-term. This is because predictive tools and properly trained and educated personnel can help eliminate costly aftermarket purchases, LOT Buys, redesigns, and other expensive DMS alternative resolutions. Rather than reacting to DMS occurrences as emergencies, AFMC's Focal Points can plan redesigns, upgrades, or other solutions

[64] Air Force Materiel Command DMSMS Program Assessment, 22 AUG 95.

in advance and save "billions of dollars across the USAF."[65] And planning for upgrades and design changes ahead of time means constant potential for system improvement – an aim that Air Combat Command's pilots will surely embrace.

LACK OF UNDERSTANDING ABOUT THE PROBLEM

One of the major observations of this research project has been that the complexity of this problem and the general lack of understanding about it have led Air Force leaders to ignore the problem. The onus for making DMS a higher-priority problem among Air Force leaders lies with DMS-affected personnel. They must make efforts to convince their leadership of the importance of this problem and its potential negative future effects.

RECOMMENDATIONS

Given this analysis of current Air Force practices, the following recommendations seek to address the three specific Problems identified in this Exercise.

PROBLEM 1

A number of the ICs in current-use USAF avionics system are no longer produced; their manufacturer(s) have exited the market. Often the Air Force receives this information on very short notice or discovers this occurrence through an unsuccessful attempt to purchase

[65] This information is quoted from a letter by Lieutenant Colonel Vincent Adamski, USAF., entitled "Wholesale Approach to Diminishing Manufacturing Sources and Material Shortages (DMS) Management."

the discontinued part. What steps can be taken to continue the flow of replacement ICs to the fighter aircraft?

AFMC has developed extremely robust solutions to this difficult problem. The Case Resolution Guide and the DMS Options Worksheet both indicate this. This problem essentially forces AFMC Focal Points into a reactive stance. AFMC Focal Points are handling this portion of the problem in the best manner that can be expected given their resource constraints.

One recommendation does flow from the analysis of Problem (1): The Hub should maintain a history of budget resources devoted to the DMS problem across AFMC support organizations in order to calculate possible savings that such a predictive tool could provide. Taking such action is an important prerequisite to the steps necessary to address problems (2) and (3).

PROBLEM 2

A number of ICs currently in use in USAF avionics systems on the F-16 and F-22 are still being produced by their manufacturers, but those manufacturers will exit the market sometime in the future. Often these manufacturers give Air Force support personnel little or no notice of their product discontinuance in order to remain competitive in the market. The Air Force currently lacks the capability in many instances to determine when this will happen. What steps can the Air Force take to provide itself the ability to predict and plan for these occurrences?

(1) Fund and execute completely the API Program. A sustained effort will be required to populate the API database with correct data, and funding will have to remain stable for that program until its completion. After completing the initial API, funding should adjust to a level that enables new weapon systems to be entered into the database as they become part

of the Air Force inventory. Expert data management contractors should execute this data management task. Multi-year contracts based on projected workloads would provide additional insurance for program completion, historically a significant challenge.

(2) Once the API is populated with the appropriate information for each weapon system, this data must be transferred to the appropriate databases used by both descriptive and predictive analytic tools. AFMC retains a number of tools like the AVCOM database that provide descriptive analysis for DMS managers but need to be populated with data. Descriptive tools enable cross-system analysis and assure proper information flow to affected weapon systems personnel. Predictive models allow DMS Focal Points to incorporate knowledge of DMS occurrences into their planning process and determine more appropriate solutions than reactive response allows. The transfer of data from the API program into these databases is both possible and practiced. In a recent AFIT-sponsored thesis, Lieutenant Michael J. Gravier concluded that "statistical modeling of DMSMS presence is not only possible, but with easily accessible data becomes quite practicable."[66] This makes clear the necessity of the API for developing a predictive capability.

(3) While the API should form a DoD-wide common database for weapon systems, the Air Force must contract with several firms to provide the predictive analysis necessary for DMS management. Sole-sourcing this function would be a poor assumption of risk. Funding should be allotted to allow the Air Force DMSMS Program to hire two contractors to

66 Gravier, Michael J. "Logistic Regression Modeling of Diminishing Manufacturing Sources for Integrated Circuits," September, 1999, 101.

perform this function, and this funding should be structured to reward the most accurate analysis. Yearly re-assessment of this contract provides an accountability mechanism and incentive for contractor performance.

(4) Because of their ability to capture a greater potential market, COTS integrated circuits will generally prove more resistant to DMS occurrences. ICs with large commercial customer bases will provide vendors with incentives to produce the IC for longer periods. The use of COTS ICs then will become more common with the acceleration of DMS predictive capabilities. This means that Air Force systems will need to run software compatible with these COTS ICs rather than developing software and then creating ICs specifically for that software. Thus software expertise should become a greater educational focus for Air Force professionals. AFIT and other graduate programs should concentrate funding into educating Air Force personnel in this critical profession.

(5) The Air Force should create a separate budget within AFMC for the management of DMS problems. This budget should buttress the existing DMS expertise in the AFMC DMSMS Program. Removing this budget from the protected budgets of SPOs and ALCs will enable a central DMS management effort to assess objectively AFMC's priorities and options in resolving DMS situations. Creating a central DMS resolution organization also provides the opportunity for development of expertise in this arena.

(6) AFMC DMS-affected personnel must raise awareness of the challenges they face now in providing a continuous IC support stream for Air Combat Command's fighters, and especially the potential impact of this problem in the future. The DMS Hub, along with affected personnel in SPOs and ALCs, must come up with creative and engaging ways to

"sell" the importance of this problem to Air Force leaders – from the top down. Part of the challenge in this case will be getting the proper audience. This audience will likely be a group of senior pilots who rightly hold the warfighter's perspective and desire for a superior, mission-capable aircraft. Without an understanding of the complexity, magnitude and scope of the problem, the leadership has no real incentive to provide resources for developing DMS predictive tools. Because the support community has handled the problem effectively to this point, it is difficult for these leaders to understand the potential future impact DMS could have. A good strategy for selling this problem is to develop a model that predicts some of the future effects that DMS and obsolescence could have on a few key weapon systems and demonstrates potential aircraft grounding rates or reduced mission completion rates in a future based on current DMS funding.

(7) Future research efforts should focus on the potential cost-savings of developing a "smart" strategy for DMS. A "smart" strategy would entail reliance on a set of predictive capabilities that allow Focal Points to plan and to design around likely future DMS occurrences. The AFMC DMSMS Program has performed some estimates in this area and should continue to assess possible savings and present these findings to the relevant decision-makers.

PROBLEM 3

When selecting a new IC for use in an avionics system, the Air Force must recognize the possibility of the vendor for that IC discontinuing production before the Air Force's operational needs end. What steps can the Air Force take to provide itself the ability to avoid, or at least decrease the probability of, this situation when selecting a new IC?

(1) Each of the solutions suggested for Problem (2) apply equally to Problem (3).

(2) The additional step necessary for resolution of Problem (3) is to incorporate DMS predictive capabilities into the Engineering and Manufacturing Development phase of future avionics systems. This will require information-sharing efforts with contractors, the Systems Engineering Community, and AFMC DMS Focal Points.

CONCLUSION

Air Force management of DMS occurrences is currently not a major problem. The major problem is that current practices will not provide Air Force personnel with the tools they will need to deal with DMS as the IC market continues to accelerate. As technological advancements in ICs continue, it will be important for the Air Force to develop a healthy respect for this coming challenge and to properly plan for DMS possibilities in its weapon systems.

This report has highlighted some major areas for further research. Budget experts should analyze the costs of DMS in different weapon systems and total them across AFMC. This should be compared with potential savings from optimal choices and predictive planning capability. Also, DMS problems should be analyzed from the perspective of other weapon systems and across other players in the complex DMS resolution process. Similarly, DMS problems do not only occur in integrated circuits or avionics systems, but across many categories of parts and systems in Air Force systems. While ICs may be the Air Force priority for this problem and the study of choice for this report, other components of USAF systems deserve similar examination.

Further research on this problem is necessary because only a body of information will enable a truly accurate assessment of what practices exist now and what possibilities exist for the future.

Avionics performance will remain at the heart of the Air Force technological edge for the foreseeable future. The acceleration of the integrated circuit market and the rapid technological changes that will accompany that acceleration will make it difficult for Air Force support personnel to keep their aircraft flying. Steps taken now towards preventive solutions to the DMS challenge can help assure the US Air Force's technological edge and utility as the tool of choice in the modern international security environment.

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http://www.rand.org/organization/paf

Air Force Doctrine Center
http://www.doctrine.af.mil

TACTech, Inc. Official Website:
http://www.tactech.com

APPENDIX A: EXAMPLE PRODUCT DISCONTINUANCE NOTICE

From: DMS Technology Center (DTC)
Date: 15 March 2000
Subject: RAN / DTC# 2000-039 / Motorola
Reference: Notification #:4885 / GIDEP X1-D-00-28

The DTC is sending the following Motorola alert for your review.

If you have any questions in regards to the DTCs' obsolescence management capabilities.
Please contact Keith Meyer at
meyer_k@crane.navy.mil
Phone: 812-854-2441
http://dtc-dms.crane.navy.mil

TITLE: MPC821 END-OF-LIFE ANNOUNCEMENT
LAST BUY DATE: 31-DEC-2001 LAST SHIP DATE: 30-JUN-2002
AFFECTED CHANGE CATEGORIES
AFFECTED PRODUCT DIVISIONS
NETWORK SYS
ADDITIONAL RELIABILITY DATA: None Ref:
SAMPLES: No Ref:
For any questions concerning this notification:
REFERENCE: MIKE SHOEMAKE PHONE: (512) 895-3823
DISCLAIMER:
CUSTOMERS MUST NOTIFY MOTOROLA IN WRITING WITHIN 90 DAYS OF RECEIPT OF THIS NOTIFICATION IF THEY CONSIDER THE DISCONTINUED PRODUCT TO BE "SOLE SOURCE." MOTOROLA AND THE CUSTOMER MAY NEGOTIATE AN APPROPRIATE END-OF-LIFE
GPCN FORMAT: CUSTOMER
DO NOT REPLY TO THIS MESSAGE.
1
Motorola Page:2
Semiconductor Products Sector
****
PRODUCT DISCONTINUANCE
****
ISSUE DATE: 30-Jun-1999 NOTIFICATION #:4885
LAST BUY DATE: 31-Dec-2001 LAST SHIP DATE: 30-Jun-2002
DESCRIPTION AND PURPOSE

Motorola does not recommend the use of the MPC821 for new designs. The MPC821 devices are being discontinued.
There are no planned enhancements or changes to the MPC821 beyond the current silicon revision B.3. Therefore, as CMOS technologies rapidly migrate to higher levels of integration and smaller geometry's, efficient manufacturing of low volume, older technology devices, by Motorola, is no longer viable. Therefore, Motorola is formally announcing an end-of-life for the MPC821. The MPC821 end-of-life will span three years.
We are providing this notification to allow our valued customers time to plan for the placement of lifetime buys with Motorola.
The replacement recommendation for the MPC821 is the MPC823 series. The MPC823 series provides 2 SCC's and a LCD/video controller making it a well-suited replacement for the MPC821.

This PCN will serve as the lifetime buy announcement. The lifetime buy announcement means that the MPC821 can be ordered until December 31, 2001 and shipments can be scheduled for an additional 6 months to June 30, 2002. Lifetime buys are non-cancelable, non-returnable. Please do not hesitate to contact your local Motorola SPS sales representative if you need additional information.

POSSIBLE REPLACEMENT PARTS

The replacement recommendation for the MPC821 is the MPC823 series. The MPC823 series provides 2 SCC's and a LCD/video controller making it a well-suited replacement for the MPC821.

FILE FORMAT: ASCII TEXT
FONT - Courier
SIZE - 12 Point
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PAGE - 55 lines/page
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AFCTD DEVICE (W/O SPECIALS),FORMAT: PN, REPL MOT PN, NON MOT INFO

MPC821ZP
PPC821ZP25B
PPC821ZP25B2
PPC821ZP25B3
PPC821ZP50A42
PPC821ZP50B
PPC821ZP50B2
PPC821ZP50B3
PPC821ZPA42
PPC821ZPA43
PPC821ZPB
SPAK820ZP50A
SPAK821CZP25B3
SPAK821ENZP25
SPAK821MZP25B3
SPAK821MZP50B3
SPAK821ZP25
SPAK821ZP25A
SPAK821ZP25B
SPAK821ZP25B3
SPAK821ZP50B
SPAK821ZP50B3
SPAK821ZP66B3
XPC820ZP50A
XPC821CZP25B
XPC821CZP25B3
XPC821MZP25B3
XPC821MZP50B3

XPC821MZPB3
XPC821ZP25
XPC821ZP25A
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XPC821ZP50B
XPC821ZP50B2
XPC821ZP50B3
XPC821ZP66B3
XPC821ZPA
XPC821ZPB
XPC821ZPB2
XPC821ZPB3
XPC821ZPB3

APPENDIX B: DMSMS CASE RESOLUTION ANALYSIS WORKSHEET

DMSMS CASE RESOLUTION ANALYSIS WORKSHEET

Date:
Analyst/Phone:
Case No.

MANUFACTURER:	P/N	DRAWING NO.	NSN:
NHAs			

Cost Calculations For: **AFTERMARKET MANUFACTURERS**
Engineering & Risk Assessment/Comments

Source	Execution Time frame	Minimum Future I Cost

Cost Calculations For: **SUBSTITUTION**
Engineering & Risk Assessment/Comments

Source	Execution Time frame	Minimum Future Cost

Cost Calculations For: **REDEFINING REQUIREMENT TO ACCEPT COMMERCIAL ITEM**
Engineering & Risk Assessment/Comments

Source	Execution Time frame	Minimum Future Cost

Cost Calculations For : **EMULATION**
Engineering & Risk Assessment/Comments

Source	Execution Time frame	Minimum Future Cost

Worksheet 3, Page 1

DMSMS CASE RESOLUTION ANALYSIS Date:
WORKSHEET, PAGE 2 Analyst/Phone:
Case No.

Cost Calculations For: **LIFE-OF-TYPE (LOT) BUY**		
Engineering & Risk Assessment/Comments		
Source	Execution Time frame	Minimum Future Cost
Cost Calculations For: **DEVELOPING NEW SOURCE**		
Engineering & Risk Assessment/Comments		
Source	Execution Time frame	Minimum Future Cost
Cost Calculations For: **RECLAMATION**		
Engineering & Risk Assessment/Comments		
Source	Execution Time frame	Minimum Future Cost
Cost Calculations For: **REDESIGN**		
Engineering & Risk Assessment/Comments		
Source	Execution Time frame	Minimum Future Cost

Worksheet 3, Page 2

DMSMS CASE RESOLUTION ANALYSIS Date:
WORKSHEET, PAGE 3 Analyst/Phone:
Case No.

Cost Calculations For: **CONTRACTOR MAINTAINED INVENTORY**		
Engineering & Risk Assessment/Comments		
Source	Execution Time frame	Minimum Future Cost
Cost Calculations For : **PRODUCTION WARRANTY**		
Engineering & Risk Assessment/Comments		
Source	Execution time frame	Minimum future Cost
Cost Calculations For: **REVERSE ENGINEERING**		
Engineering & Risk Assessment/Comments		
Source	Execution Time frame	Minimum Future Cost
Cost Calculations For		
Engineering & Risk Assessment/Comments		
Source	Execution Time frame	Minimum Future Cost

Worksheet 3, Page 3

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1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	22.Aug.00	MAJOR REPORT

4. TITLE AND SUBTITLE
ADAPTING AIR FORCE PRACTICES TO COPE WITH A VANISHING INTEGRATED CIRCUIT SUPPLY BASE - MAINTAINING THE TECHNOLOGICAL EDGE

5. FUNDING NUMBERS

6. AUTHOR(S)
2D LT RAINES CHRISTOPHER R

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
HARVARD UNIVERSITY

8. PERFORMING ORGANIZATION REPORT NUMBER
CY00359

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

20000831 094

14. SUBJECT TERMS	15. NUMBER OF PAGES
	81
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT